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BEFORE THE
POSTAL REGULATORY COMMISSION

Periodic Reporting	)	Docket No. RM2016-2
(UPS Proposals One, Two and Three)	)	

DECLARATION OF JOHN C. PANZAR
ON BEHALF OF
AMAZON FULFILLMENT SERVICES, INC.

January 25, 2016

1. Introduction and Summary

My name is John C. Panzar. I am Professor of Economics in the Business School of the University of Auckland and Louis W. Menk Professor of Economics, Emeritus at Northwestern University. My professional work has included analysis of economic pricing and costing principles for the United States Postal Service and other multiproduct firms. I have sponsored testimony to the Postal Rate Commission ("PRC" or "the Commission") on behalf of several parties (and the Commission itself). In 2014, the Commission contracted with me to prepare a report on the proper role of costs for postal regulation.[1] My curriculum vitae is attached as Exhibit 1 to this Declaration.

The purpose of this Declaration is to evaluate the first proposal made by United Parcel Service, Inc. ("UPS") in its October 8, 2015, petition for rulemaking in this docket ("UPS Proposal One")[2] and to discuss arguments made in support of the proposal by Dr. Kevin Neels in his Report filed on the same date ("Neels' Report").[3] For the reasons explained in the following pages, the Commission should not adopt UPS Proposal One.

The objective of the proposal is straightforward: without modifying the basic structure of the Postal Service's Cost and Revenue Analysis ("CRA") system, the proposal would *attribute all* component variable costs to individual services. UPS Proposal One

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[1] Panzar (2014).

[2] UPS Proposal One — A Proposal to Attribute all Variable Costs Caused by Competitive Products to Competitive Products Using Existing Distribution Methods (filed in Docket No. RM2016-2 on October 8, 2015).

[3] Report of Dr. Kevin Neels Concerning UPS Proposals One, Two, and Three (filed by UPS on October 8, 2015).

would require this attribution even for costs that would not be avoided by even the complete elimination of the service being costed.

UPS Proposal One, while easy to understand and implement, would violate the requirements for economically sound cost determination and pricing in multi-product enterprises. The chain of logic is quite simple: (1) The Postal Accountability and Enhancement Act ("PAEA") requires that the cost attributed to a service (or subset of services) be *causally related* to that service (or subset of services); (2) according to economic theory, the cost *caused* by a service (or subset of services) equals the *incremental cost* of that service (or subset of services)—i.e., the extra costs that result from providing the increment of service, or would be avoided by *not* providing it; and (3) the infra-marginal component costs that UPS Proposal One seeks to attribute to individual services (or subset of services) are *jointly caused* by *all* services using the component but are *not* caused by any particular service (or subgroup of services).

The adverse economic effects of UPS Proposal One would result from its impact on the minimum prices the Postal Service would be allowed to charge for its competitive (i.e., non-market dominant) services. Economists generally agree that economic efficiency and the avoidance of cross-subsidization requires that the prices charged for products offered by multiproduct firms like the Postal Service satisfy three tests: (1) the price charged for an individual (or marginal) unit of output must cover its marginal cost; (2) the *average* revenue received for any larger increment of output of a product must cover its *average* incremental cost; and (3) the *total* revenue received from two or more products combined must cover the

incremental costs of the same products combined.[4] Above these price floors, a regulated firm like the Postal Service should be allowed to recover the shortfall between incremental costs and total costs by setting markups that, in the judgment of Postal Service management, maximize the total contribution generated by the Postal Service's outputs, constrained only by the maximum rate standards and restrictions on discrimination that legislators and regulators set. Regulators should not impose minimum price floors that include costs that are not caused by the increment of output being costed (in the sense of being avoided if the incremental output were not provided).

UPS Proposal One would violate these economic standards by adding various infra-marginal costs to the incremental costs of each service and by requiring that minimum Postal Service prices for individual competitive products cover this inflated measure of cost *even when the contribution-maximizing Postal Service price for the competitive product was below the resulting price floor.* Two undesirable effects are likely to result from this change. First, the Postal Service would lose to rivals volumes for which it was actually the most efficient provider. This would make mailers and consumers worse off by diverting volume from the carrier with the lowest costs to society. It would also make the Postal Service (and, ultimately, mailers and consumers) worse off by depriving the Postal Service of contributions to institutional costs that the Postal Service could have earned when contribution-maximizing prices are below the UPS-proposed price floor. Second, competitors of the Postal Service would be able to increase their prices on the volumes they

[4] This result was established for regulated industries in the classic contribution of Faulhaber (1975). See also the discussions in Baumol, Panzar and Willig (1988), OIG (2012), Panzar (1989) and Panzar (2014)

carry because the threat of price competition from the Postal Service would be limited by the higher level of the price floor.

The remainder of this Declaration proceeds as follows. Section 2 briefly reviews the relevant economic principles. Second 3 presents a brief review of the role of costs in postal policy under PAEA. Section 4 critiques the arguments made in support of the UPS proposal in UPS Proposal One and related sections of the Neels Report. Section 5 develops a simple example to illustrate the implications of replacing the theoretically correct incremental cost standard with one based on that in UPS Proposal One. The final section offers a brief conclusion.

2. The Basic Economic Principles

To an economist, there is a *causal relationship* between the quantities of economic goods and services produced by a multi-product entity and the costs incurred by that entity. ***Total costs*** consist of all costs caused by the production of the specified quantities of *all* products produced by the firm, and would vanish, at least in the long run, if the firm ceased all production.[5]

Incremental costs equal the costs that are caused by the production of a given subset of a firm's outputs. Stated conversely, incremental costs are the costs that would be avoided if a given subset of the firm's outputs were discontinued. The parallel emphasis on the concept of *avoided cost* is particularly important as a guide to intuition. Because costs are often "brought into existence" jointly or in common by a number of different products or

[5] For a more formal and detailed discussion of these concepts, see Panzar (2014), which I attach for ease of reference as Exhibit 2 to this Declaration.

services, one can get caught up in a "chicken and egg" confusion based upon hypothetical scenarios concerning the *order* in which products were introduced into the firm's portfolio. Indeed, the costs of *adding* a particular product (or group of products) will differ depending on the mix of products already present. However, it is unambiguously clear that the only *added costs* that are equal to *avoided costs* are those that result when the product (or group of products) in question is added *last*. And, that is precisely the cost measured by the economic definition of incremental costs.[6]

Marginal cost is the incremental cost of a single unit of output, or the cost avoided by not producing a single unit of output. In mathematical terms, marginal cost is the limit of the average incremental cost as the size of the increment approaches zero. Thus, the marginal cost of any particular service is defined as the partial derivative of total cost with respect to the volume of that service.

All measures of incremental cost share a fundamental trait in common: they exclude, by definition, any costs that would still be incurred even if the specific increment of output were eliminated.

Variable costs vary continuously with volume.

[6] This is discussed in more detail in Panzar (2014), at p. 6 (reproduced at Exhibit 2 below).

Fixed costs are costs that must be (discontinuously) incurred if the firm is to produce *any* positive amount of output. That is why fixed costs are sometimes referred to as "start-up costs." They do not vary with volume.[7]

3. The Role of Cost Attribution in Postal Regulation

The CRA costing framework was developed by the Postal Service and its regulators over the past several decades with the objective of explaining how various Postal Service cost measures can be used to guide the Postal Rate Commission and its successor, the Postal Regulatory Commission (collectively "PRC" or "Commission"), in fulfilling its pricing responsibilities, as specified in 39 U.S.C. §§ 3622(c)(2), 3631(b) and 3633(a). Of pertinence to UPS Proposal One, these statutory provisions require that prices be set so that:

> (i) The rates charged for each market dominant class of mail or type of mail service should, with some exceptions, cover the costs "attributable" to it through "reliably identified causal relationships." 39 U.S.C. § 3622(c)(1).[8]
>
> (ii) The Postal Service should not be allowed to use revenue from its market-dominant products to subsidize its competitive products. 39 U.S.C. § 3633(a)(1).

[7] Fixed costs are important, both in theory and in practice. However, they are notoriously difficult to measure empirically. This is because available data tend to be generated by output levels very far from the origin (i.e., zero). Using these data to infer the size of any start-up costs would necessitate a great deal of relatively unreliable extrapolation. The separate Declaration of T. Scott Thompson discusses this in more detail.

[8] I understand that the Commission has recognized several exceptions to the attributable cost price floor for market-dominant products. Those exceptions are not germane to this Declaration, and are not discussed in it.

(iii) Each competitive product must cover its attributable costs. 39 U.S.C. § 3633(a)(2). The law defines these costs as the "direct and indirect postal costs attributable to such product through reliably identified causal relationships."[9]

Interpreting these terms requires an understanding of how Postal Service cost concepts such as *volume variable costs*, *infra-marginal costs* and *institutional costs* are related to established economic cost concepts such as *marginal costs*, *incremental costs*, *fixed costs* and *variable costs*. Perhaps most importantly, one must determine the *economic* meaning of the statutory term "attributable" and relate it to the concept of *attributable costs* as defined by the Postal Service in the CRA. I analyzed this question in some detail in my 2014 report to the Commission. Panzar (2014) (reproduced as Exhibit 2). My results may be summarized as follows:

(1) The statutory use of "attributable" clearly specifies that there be a *causal relationship* between the product provided and the costs attributed to it. Identifying the relevant economic cost condition is equally straightforward: the costs *caused* by a product (or group of products) are, by definition, the incremental costs of that product (or group of products). Therefore, statutory attributable costs should be interpreted as excluding any costs that are not caused by the increment being costed—or, stated otherwise, would not be avoided if the increment of output were discontinued.

[9] 39 U.S.C. § 3633(a)(3) and (b) contains a further requirement that competitive products, taken together, collectively cover an "appropriate share of the institutional costs of the Postal Service." This requirement is the subject of UPS Proposal 3, which the Commission has set aside for consideration later.

(2) The CRA methodology defines attributable costs in a way that only partially aligns with the economic definition of incremental costs. In general, CRA attributable costs understate economic incremental costs when, as appears to hold for many Postal Service cost segments, marginal costs are declining over the relevant range of output.

(3) The difference between the current measure of attributable costs and a more economically precise measure of incremental costs appears to have little practical significance, however, in the pricing of competitive products. Except when the increment of volume at issue represents a large share of total Postal Service volume, the difference between the two cost measures is small. All competitive products collectively account only a relatively small fraction of total Postal Service volume.

(4) In any event, the accounting data generated by the CRA can be used to calculate the economic incremental costs of Postal Service products. Panzar (2014), at pp. 2, 23-25.

These conclusions were based upon more than two decades of economic research on postal costing methodology. To summarize briefly, Postal Service costing is designed to deal with the multiservice nature of postal operations through a two stage procedure.[10] The first step is to determine the variability factor for each of several cost components: i.e., the

[10] Bradley, Colvin and Smith (1993) first explained the relationship between Postal Service costing relationships and economic concepts such as marginal cost. Subsequent work by Bradley, Colvin and Panzar (1997, 1999) further explained how Postal Service cost accounts can be used to calculate the incremental cost of various services.

elasticity of component variable cost with respect to the level of that component's cost driver activity. For each component, this variability factor is multiplied by total component variable costs to obtain the level of component *volume variable costs*.

Next, the CRA attempts to trace the impacts of individual service levels (volumes) on the levels of the cost drivers required to meet them. It does so by specifying, for each service, a relationship between service volumes and driver activity (i.e., "distribution keys") on a component by component basis. These distribution keys are used to divide each component's volume variable costs to individual services. Finally, for each service, these distributed volume variable costs are summed over all the cost components. The result is the service's (total) volume variable cost. Dividing this total by service volume yields the key Postal Service cost benchmark for each of its services: service level *unit volume variable cost*. The somewhat surprising result of this rather involved exercise is that unit volume variable cost corresponds exactly to the economic definition of marginal cost.[11] This is an extremely important result because marginal costs are an essential ingredient in the pursuit of any policy objective for the regulated firm. Regardless of the objective of the firm or its regulator, appropriate pricing policy requires reliable estimates of each product's marginal cost.

Despite being critical of the current definition of attributable costs, I also pointed out in my 2014 report that the methodology used in the CRA can be readily extended to

[11] "Thus, the CRA's 'volume variability approach' to costing provides accurate measures of marginal cost on a product by product basis." Panzar (2014), p. 15.

accurately measure the incremental costs of individual products using available CRA information on component costs.

> In any event, "correcting" Postal Service attributable costs to accurately measure a product's incremental cost should be a straightforward 'spreadsheet calculation' based upon available component cost information. Then, the PRC would have the information upon which to base pricing policy (i.e., unit volume variable costs) and test for cross-subsidization at the product level (i.e., incremental costs).

Panzar (2014), p. 15. In any event, as noted above, the current measure of attributable costs appears to be a reasonably close proxy for incremental costs as long as the increment being costed is a relatively small fraction of total Postal Service volume (as is true of competitive products both individually and in the aggregate). Panzar (2014), pp. 23-25.

3. Critique of the UPS/Neels Rationales for Proposal One.

UPS Proposal One and the Neels Report present a clear exposition of the basic methodology used in the CRA. Their discussion and diagrammatic analysis illustrate the nature of the current dispute. In this section, I will not restate their arguments in detail. The gist of UPS Proposal One is straightforward, however. It would require that the minimum prices allowed for every mail class and product whose production uses a cost component must include an allocated or distributed share of *all* inframarginal costs of the cost component—including costs that would *not* be avoided by the discontinuance of the increment of volume at issue, and therefore are not part of the incremental costs of that volume.

Adopting this remarkable proposal would require the Commission to abandon the very concept of incremental cost and, indeed, cost causation itself. Proposal One would

jettison the linchpin of incremental costing: the principle that the incremental cost of a given unit of output is a *ceteris paribus* measure of cost. Incremental cost is the measure of a specified *change* (increment) in output, with the other outputs of a firm as a given. Incremental costing asks what *added* costs would be caused by providing the specified extra increment of output, or (stated otherwise) what costs would be *avoided* by discontinuing the specific increment of output. UPS Proposal One, by contrast, would lump together *all* variable costs, whether caused by or invariant to the increment of volume at issue, and require that the unit price for *every* output cover the resulting average cost. For cost components whose provision requires some fixed (start-up) costs, UPS Proposal One would require that the price floor cover the average variable cost incurred in producing *all* of the outputs that use the cost component. For the many cost components that are estimated with a constant cost elasticity function (i.e., which are estimated to have no fixed or start-up costs), UPS Proposal One would require that minimum prices cover the fully distributed cost ("FDC") of that component.

For the reasons that I next explain, none of the arguments advanced by UPS and Dr. Neels justify this extraordinary result.

3.1 Because not all Infra-Marginal Costs are *Caused* by Individual Products, the Requirement that Prices for all Competitive Products Cover their Attributable Costs Does Not Mean that Prices Must Cover all Infra-Marginal Costs.

As UPS notes, PAEA requires that the rates charged for competitive products cover the costs that are directly and indirectly "attributable" to those products "through reliably identified causal relationships." UPS Proposal One (p. 12) (citing 39 U.S.C. §§ 3631(b) and

3633(a)(2).) Not all infra-marginal costs, however, are caused by individual competitive products (or even all competitive products combined). For the same reason, the prohibition against cross-subsidy of competitive products, 39 U.S.C. § 3633(a)(1), does not require that the price of each competitive product (or all competitive products together) cover a distributed allocation of the aggregate infra-marginal costs of the cost components used to produce the product or products(s).

It is true that *all* the variable costs of a cost component are *caused* by the volumes of the services that collectively use the cost driver of that cost component. The causal relationship between the collective volumes and those variable costs, however, is joint, not individual: the costs are *jointly caused* by *all* the services that utilize that component's cost driver. The costs that are *caused* by a *particular* service (or subset of services) are only those costs that (i) are brought into existence by adding the service (or subset of services); *or* (ii) are *avoided* if the provision of that service (or subset of services) were discontinued: i.e., the incremental costs of that service (or subset of services). As explained above and in my 2014 report to the Commission, the concept of avoided cost, and the *ceteris paribus* nature of incremental cost, are key to understanding the nature of causation that underlies incremental cost.

In a multiservice enterprise, this distinction, while perhaps subtle, is crucial. For a component in which the level of driver activity is jointly determined by the volumes of many services, the resulting component costs are jointly caused by *all* of the services. To recognize this, as the Commission did in the passage cited in UPS Proposal One, does *not* imply that any *particular* portion of variable costs (e.g., infra-marginal costs) must be

attributed to any *particular* service (or subset of services). A passage from the Commission's recommended decision in R80-1, which UPS quotes on page 14 of its Proposal One, illustrates this distinction:

> That variability with volume should be sufficient to establish causality is not difficult to understand. It is almost tautological. A variable cost is one that will change *because* of a change in the volume of a class of mail. A finding of variability is thus simultaneously a finding of causation.[12]

While the quoted statement is unexceptionable, UPS begs the question raised by Proposal One: *what* costs vary with *what* volume changes. The third sentence of the quotation provides the answer: "A variable cost is one that will change because of a change in the volume of *a class of mail*." *Id*. (emphasis added by me). Costs that vary with *total* volume of all products may be attributed to all volume *as a whole*. Costs may not be attributed to any *particular* mail class or other subset of total volume, however, except to the extent that the costs vary with *that subset* of volume.

3.2 The Incremental Cost Test *Is* Sufficient to Ensure That Competitive Products Bear An Adequate Level of Costs.

Next, UPS Proposal One argues that attributing infra-marginal costs is necessary to prevent unfair competition by the Postal Service:

> If the Postal Service is allowed to disregard large volumes of variable costs when setting prices for its competitive products, then it is allowed to compete unfairly, on a playing field that is heavily tilted in its favor.

UPS Proposal One, p. 14. It is difficult to see what the Postal Service would gain by "disregard[ing] large volumes of variable costs when setting prices for its competitive

[12] R80-1 Op. & Rec. Decision, App. B, p. 26 (Feb. 19, 1981) (emphasis in original).

products." Ignoring costs does not make them go away. On the other hand, if the Postal Service were able to *avoid* "large volumes of variable costs" (by, say, shifting them to dominant service customers or increasing its deficit), its competitive operations might be said to have an unfair advantage over its rivals. However, an incremental cost price floor prevents both of these outcomes because prices that satisfy the incremental cost test ensure that neither the customers of the enterprise's other services nor the enterprise itself are made worse off by the fact that the competitive services are offered.

UPS gains nothing with its related (and equally remarkable) claim that attribution of all infra-marginal costs, including the portions in excess of the incremental costs of competitive products, is necessary to prevent the Postal Service from capturing the "benefits" of its economies of scale and scope for itself:

> This modification [i.e., the attribution of all infra-marginal costs] is necessary to ensure that the Postal Service's competitive products business is competing fairly and that it is not being allowed to ride nearly for free on a delivery network paid for almost entirely by market dominant products. The Postal Service's competitive products business will still enjoy some benefits of the economies of scope and scale created by mailers held captive by the letter monopoly, but it will just not be able to enjoy *all* of those benefits.

UPS Proposal One at p. 25 (emphasis in original). This statement gives away the game. When a multi-product firm has economies of scale and scope, it is entirely efficient for the firm to pass through most (or even all) of the economies to customers in competitive markets through lower prices, as long as the rates paid by the competitive customers cover the marginal and incremental costs of serving them.[13] In any event, this claim also ignores

[13] See Braeutigam (1989), at pp. 1337-1341, for a thorough discussion of cross-subsidization and its effects.

39 U.S.C. § 3633(a)(3) and (b) which require that competitive products make a minimum contribution prescribed by the Commission to the institutional costs of the Postal Service: i.e., to pass through some of the economies of scale and scope to users of market dominant mail products.

Finally, UPS gains nothing by citing recent Commission statements that per unit attributable costs (and per unit incremental costs) should include more than marginal costs (i.e., per unit volume variable costs). UPS Proposal One, p. 16. This proposition is correct, but irrelevant. As I discussed in my 2014 report to the Commission, the incremental cost of a product will typically exceed its volume variable cost, and avoidance of cross-subsidy requires that the average revenue from each relevant increment of output cover the average incremental costs of that increment. As I also noted in the same report, however, the correct incremental cost measure can be readily estimated using available information from the CRA. Further, the Commission's current measure of attributable cost appears to be a reasonable proxy for the incremental costs of individual competitive products, and even all competitive products combined. In any event, the proposition that the incremental cost floor is likely to be somewhat higher than marginal or attributable cost hardly justifies adoption of a cost floor that by design exceeds incremental cost as well.

3.3 Infra-marginal Costs *Can* be Allocated to Products Using Existing Distribution Methods, but the Commission Should Not Do So!

UPS's arguments concerning the role of distribution keys in the Postal Service CRA betray a similar confusion. The UPS argument seems to be as follows: The Postal Service uses its distribution keys to distribute total component volume variable costs to obtain the

component volume variable costs assigned to each product – therefore they must be causally valid. This means that using the same distribution keys to assign total component infra-marginal to individual products must also be causally valid.

This reasoning ignores the difference between the purposes of the distribution keys in the CRA versus UPS Proposal One. If (i) the distribution keys are valid; and (ii) the component variability factor is correct; then, the volume variable costs assigned to each service will be exactly equal to the marginal cost of that service multiplied by the quantity of that service.[14] This means that the *per unit* volume variable cost of a service provides an accurate measure of the *marginal cost* of that service. This is why the distribution of component volume variable costs to each service is very useful. Marginal cost is a very important piece of information for firm decision making.

The use of distribution keys to estimate *incremental* costs stands on a very different footing. Applying a distribution key to the total variable costs of a cost component used to supply multiple outputs does not directly measure the cost that would be avoided if *all* the units of any one (or several) of those outputs were eliminated. Indeed, as I explained in my 2014 report to the Commission, cost distribution keys cannot directly establish cost causality:

> However, it is important to avoid the temptation to view the volume variable costs *distributed* to a particular product as being *caused* by that product. The variable costs of a component are *jointly* caused by *all* the volumes of *all* the products that utilize that component. These costs may be *distributed* to individual products based on that product's share of driver activity. However,

[14] See Bradley, Colvin, and Smith (1993), Bradley, Colvin, and Panzar (1997, 1999), OIG (2012) and Panzar (2014).

> unless component marginal cost is constant, the resulting cost distribution to product *i* is *not* the amount of cost that would be *avoided* if product *i* were to be discontinued: i.e., it is not the incremental cost of product *i*.

Panzar (2014), p. 13 (Emphasis in original).

UPS Proposal One would use these same distribution keys to distribute *all* component variable costs (i.e., the sum of component volume variable costs and component infra-marginal costs) to individual services. As I explained in detail in my 2014 report, this would lead to an overstatement of the incremental cost of an individual service (or subset of services).

3.4. The Shapley method of cost allocation is not an appropriate way to determine Competitive Price Floors.

The Neels' Report argues in great detail that UPS Proposal One has a venerable and widely respected intellectual antecedent: i.e., the Shapley Value. The Shapley Value is, indeed, an elaborate method for allocating the joint and common costs of multi-output firms to individual outputs. In the current context, application of the Shapley method indisputably would have the effect of allocating the infra-marginal costs of each component in the same proportions as those in which volume variable costs are distributed. The resulting allocations, however, would have no relationship to marginal, attributable or incremental costs; and using the Shapley-allocated costs to set prices would be economically unsound.

For present purposes, the most important difference between economically-based cost floors and the Shapley method is their role in determining a rate floor for competitive products. Cost allocation procedures, such as the Shapley Value, do not provide the basis

for the determination of price floors for individual products (or subsets of products) by estimating the marginal, attributable or incremental costs of subsets of a firm's output. Rather, they allocate or distribute fixed, joint and common costs to individual products so that, if the firm set the price for each product exactly equal to the allocated costs, the total revenue generated by the rates would lead to the enterprise *exactly* covering its costs without any further mark-ups (assuming away the likelihood that variations in competition and demand elasticities would cause net losses of volume and contribution).[15] The Shapley approach, if applied at the product level, would not result in economically efficient prices except in the extremely unlikely event that they coincided with Ramsey prices. Likewise, the Shapley approach would not optimize the non-efficiency factors and objectives of statutory lists such as 39 U.S.C. § 3622(b) and (c) except in the unlikely event that each of the numerous products offered by the regulated firm promoted the statutory objectives to an identical degree. And the Shapley approach could inflict heavy losses on the regulated firm when the demand for its competitive products is sufficiently elastic that contribution-maximizing prices are below the levels that the Shapley approach would arbitrarily dictate.

The Neels Report and UPS Proposal One make much of the fact that the Shapley Value approach (i.e., using existing distribution keys to allocate infra-marginal costs to

[15] The Shapley approach thus contrasts with economically sound price floors, which are not intended to serve as price ceilings. If one priced all of a firm's products at an appropriate cost-based rate floor, firms with economies of scale and scope would typically incur large losses. That is why modern regulatory systems for multi-product firms with substantial economies of scale and scope recognize the existence of zones of rate reasonableness, which maximum allowed rates capped at levels which are substantially above marginal or incremental cost. Whatever the economic cost attribution principles one uses to construct rate floors, they are clearly intended to be applied to one product (or subset of products) at a time, not to all products simultaneously as rate ceilings.

individual services) is "order-neutral"[16] because "each unit of the cost driver would share equally in the attribution of infra-marginal cost."[17] In the context of determining the costs that are caused by particular outputs, however, this is not a virtue but a fundamental defect. Incremental costs, properly defined, are *not* "order-neutral." As explained above, *order* is of paramount importance when applying a rate floor. It is precisely the extra costs that result when the service (or subset of services) in question is *added last* that determines whether or not that service (or subset of services) is being cross-subsidized by the remainder of the offerings of the enterprise. And, this is precisely what incremental cost measures. Indeed, Dr. Neels himself acknowledges this basic principle:

> This incremental cost test … seeks to answer the question of whether the revenues earned by competitive products exceed the incremental costs of producing those products. As such, it involves a comparison of two states of the world – one where the enterprise offers its current set of products and one where it offers all products other than competitive products. The costs calculated in this way represent the costs that the Postal Service would avoid if it were to shut down its competitive product business. The comparison between these costs and the revenues earned by competitive products indicates whether the Postal Service would be better off financially if it were to exit its competitive products business.

(Neels Report, pp. 21-22.)

And, contrary to the view expressed by Dr. Neels in his next sentence, this is precisely the question being posed here.

[16] UPS Proposal 1, p.24.

[17] Neels' Report, p. 28.

4. One Person's Floor is Another Person's Ceiling: UPS Proposal One Benefits Competitors at the Expense of Consumers

Given that a rate floor based on incremental costs achieves the objective of ensuring that the competitive offerings of the Postal Service are not being subsidized by either the customers of its monopoly services or the enterprise itself, what would be the effects of *raising* that floor? Answering this question requires a brief review of the competitive effects of a price or rate floor. Consider the simple case in which the products of the Postal Service and its competitors are essentially perfect substitutes. There are two basic situations to consider:

(i) The initial, incremental cost – based price floor is higher than the unit cost of the competing private carriers. The market is more efficiently served by the competing private carriers and the result of price competition is that they capture the business at a price (very, very) slightly below the level of the rate floor.

(ii) The initial, incremental cost – based price floor is lower than the unit cost of the private carriers. The market is more efficiently served by the Postal Service and the result of price competition is that the Postal Service captures the business at a price (very, very) slightly below the level of the most efficient private carrier's unit cost.

Now consider the impact of raising the price floor by basing it upon Shapley Value cost allocations. In situation (i), the private carriers would continue to serve the market but at a *higher* price: i.e., one (very, very) slightly below the new rate floor. Consumers lose,

private carriers win, and the Postal Service is unaffected by the change. In situation (ii), there are two possibilities. In the first, the higher rate floor remains below the private carriers' unit costs, and there is no effect. The Postal Service continues to efficiently serve the market at the same price. The market price remains the same because the "ceiling" on the Postal Service's competitive price is determined by its competitor's (unchanged) unit cost. Alternatively, the increase in the rate floor is such that it is now *above* the private carriers' unit costs. Then, the private carriers would *inefficiently* capture the market from the Postal Service *and* consumers would end up paying a higher price (very, very) slightly below the higher rate floor.

As noted above, the latter circumstance would be harmful to consumers in another way: if the volume captured by the private carriers from the Postal Service as a result of the inflated price floor had made a positive contribution to the Postal Service, the Postal Service would suffer losses as a result. The result would be either higher prices on market-dominant services (if the regulatory scheme allows this) or, more likely, a deterioration in the Postal Service's finances and quality of service.

5. An Illustrative Example

A very simple numeric example can be used to illustrate the issues at hand. The characteristics of the example are assumed to be as follows:

1. There are two products: a "monopoly" service with volume given by Q_1; and a "competitive" service with volume given by Q_2.

2. There is a single cost component with a single cost driver, D.

3. There are no component fixed costs or product specific fixed costs.

4. Component total cost is given by the formula $c(D) = 720\sqrt{D}$. (This component cost function exhibits declining marginal costs, since $mc(D) = 360/\sqrt{D}$ is a decreasing function of the level of driver activity.)

5. For both services, each unit of volume requires one unit of driver activity. Thus, the total level of driver activity is given by $D = Q_1 + Q_2$. Thus, the total costs of the enterprise are given by $C(Q_1, Q_2) = c(D) = 720\sqrt{Q_1+Q_2}$, and the marginal costs of each service are given by $MC_1(Q_1, Q_2) = MC_2(Q_1, Q_2) = \frac{360}{\sqrt{Q_1+Q_2}} = mc(D)$.

The specification of this example is consistent with the diagrams used in UPS Proposal One, Neels' Report, and Panzar (2014).

Next, consider the relevant postal cost concepts in the context of this example:

Component Volume Variable Costs: The *variability factor* for this component has been assumed to be ½,[18] so total component volume variable cost is equal to one half of component variable costs: $VVC = \frac{C(D)}{2} = 360\sqrt{Q_1+Q_2}$.

Service Volume Variable Costs: In the example, the distribution key results from distributing component volume variable cost to services in the same proportion as their share of total volume (and driver activity): $VVC_1 = \frac{360Q_1\sqrt{Q_1+Q_2}}{(Q_1+Q_2)}$; and $VVC_2 = \frac{360Q_2\sqrt{Q_1+Q_2}}{(Q_1+Q_2)}$.

[18] As noted above, the a component's variability factor, ε, is defined to be the elasticity of component variable cost with respect to the level of component driver activity: i.e., $\varepsilon = \frac{Dmc(D)}{c(D)} = \frac{(D)\left(\frac{360}{\sqrt{D}}\right)}{720\sqrt{D}} = 1/2$.

Service Attributable Costs: In the absence of service specific fixed costs, the attributable costs of a service are equal to the volume variable costs distributed to it.

Service Incremental Costs: The incremental costs of a service are the costs that would be avoided if that service's volumes were removed.[19] In the present example these are given by:

$$IC_1 = C(Q_1, Q_2) - C(0, Q_2) = 720\sqrt{Q_1+Q_2} - 720\sqrt{Q_2}$$

$$IC_2 = C(Q_1, Q_2) - C(Q_1, 0) = 720\sqrt{Q_1+Q_2} - 720\sqrt{Q_1}$$

Component Infra-marginal Costs: By definition, component infra-marginal variable costs are given by total component variable costs less component volume variable costs:

$$IMC(Q_1, Q_2) = C - VVC = 360\sqrt{Q_1+Q_2}$$

It is now straightforward to analyse the impact of UPS Proposal One in the context of the example. For concreteness, assume that $Q_1 = 16$ and $Q_2 = 9$. Then, total component costs are $C = 3600$. The marginal costs of each service are given by $MC_1 = MC_2 = 72$. Component volume variable costs are given by $VVC = 1800 = C/2$, with service volume variable costs given by $VVC_1 = (16/25)(1800) = 1152$ and $VVC_2 = (9/25)(1800) = 648$. Finally, the incremental costs of each service are given by $IC_1 = 3600 - 2160 = 1440$ and $IC_2 = 3600 - 2880 = 720$. Next, I use this example to explain the competitive impact of the cost-based pricing restrictions imposed by PAEA.

As noted above, under 39 U.S.C. 3633(a), PAEA would require the Commission to use its powers to: (1) prohibit the subsidization of competitive products by market-dominant

[19] See Panzar (2014), definition E3.

products; and (2) ensure that each competitive products covers its costs attributable. As explained above, economists generally agree that Condition (1) comes down to the condition that each competitive service (or subset of services) passes the Incremental Cost Test (i.e., the requirement that each increment of output generate enough additional revenue to cover the incremental costs of that output). Let p_2 denote the price that the Postal Service receives for each unit of the competitive product. Then, in the present example, the Incremental Cost Test comes down to the condition that $p_2Q_2 \geq IC_2$, or $9p_2 \geq 720$ or $p_2 \geq 80$. If this condition is satisfied, it is clear that the Postal Service is better off providing the competitive service than abandoning it. To see this, let R_1 denote the revenues that PAEA price cap regulation allows the Postal Service to receive from its monopoly service. Then, when offering the competitive service, the Postal Service earns profits of $\pi\{1,2\} = R_1 + 9p_2 - 3600$. If forced to abandon the competitive service, it would earn profits of $\pi\{1\} = R_1 - 2880$. Since $\pi\{1,2\} - \pi\{1\} = 9p_2 - 720$, satisfying the incremental cost test for service 2 guarantees that the profits of the Postal Service increase when service 2 is offered.

It is important to note that Condition (2) does not provide such a barrier to cross-subsidization if the traditional Postal Service measure of attributable cost is used. Without fixed costs, the attributable costs of a service are just equal to its volume variable costs, so covering the attributable costs of service 2 would require $9p_2 \geq 648$, or $p_2 \geq 72$. Thus, there is a range of prices (between 72 and 80) that would satisfy the traditional attributable cost standard but would lead to a cross-subsidy of the competitive services.

Next, consider the price floor that would result from defining attributable costs according to UPS Proposal One. That is, each service would have distributed to it a share of component infra-marginal costs using the same distribution key used to distribute component volume variable costs. In terms of the present example, this would yield the following cost attributions for the competitive service:

$$A_2 = \frac{Q_2[VVC + IMC]}{(Q_1+Q_2)} = \frac{9 \cdot 3600}{25} = 1296$$

Requiring that the revenues from the competitive service, p_2Q_2, cover this attribution requires that the price charged satisfy $p_2 \geq 144$.

The foregoing analysis has resulted in three price floors for the competitive product. It has revealed that the incremental cost test yields a price floor (80) which exactly implements the requirement that Postal Service profits must decrease if the competitive service is dropped. The traditional Postal Service measure of attributable costs yields a lower price floor (72) which is slightly too low to always prevent cross-subsidization.[20] Finally, it was shown that the price floor (144) resulting from the implementation of UPS Proposal One would be considerably greater than either of the above; more than sufficient to prevent cross-subsidization. Put another way, while the traditional attributable cost-based price floor is too low to prevent cross-subsidization in all circumstances, *both* the incremental cost test price floor and the UPS proposed price floor are sufficiently high to

[20] In this example, marginal cost is 10% below average incremental cost. The difference is as large as it is because the example assumes: (i) a relatively large volume share (36%) for the competitive product; and (ii) very strong economies of scale for the cost component (ε = ½). It is still quite small relative to the error which would result from implementing the UPS Proposal 1: i.e., an overestimate of 80%.

always prevent cross-subsidization of competitive products. What, then, is the problem with implementing UPS Proposal One?

To see the difficulty, one must consider the competitive environment in which the price floor is to be implemented. Therefore, suppose that consumers view the Postal Service's competitive offering to be a perfect substitute for a similar service provided by UPS and that UPS's costs of providing the service are constant at f per unit. Continue to assume that consumers' demands for service 1 and service 2 are inelastic at 16 units and 9 units, respectively. In the context of this example, it is easy to determine the relative efficiency of two possible industry configurations: (i) a "monopoly" configuration in which the Postal Service is the sole provider in both markets; and (ii) a "mixed" configuration in which the Postal Service continues to be the sole provider of Service 1 while UPS captures the market for service 2.

Total postal sector costs under the monopoly configuration are, as above, equal to $TC_i = C(16,9) = 3600$. Total postal sector costs under the mixed configuration are given by $TC_{ii} = C(16,0) + 9f = 2880 + 9f$. Clearly, the choice of the most efficient industry configuration depends on the value of UPS's unit costs; i.e., on how efficient the competitor is relative to the incumbent. In this example, industry configuration (i) is most efficient whenever $f > 80$. If the market configuration were determined by an *omniscient, benevolent* Planner, the optimal outcome could result from the following simple process: UPS could apply for the right to serve market 2; if its costs were low enough (i.e., $f < 80$) the Planner would award market 2 to UPS, thereby implementing the mixed configuration. If UPS's

costs were too high (i.e., $f > 80$), the Planner would deny the entry request and retain the monopoly industry configuration.

Given the short supply of omniscient planners, modern regulatory policy tries to leave the determination of the efficient industry configuration to market forces. *If* the markets in question were perfectly competitive/contestable, the efficient outcome would emerge naturally, as a condition of equilibrium.[21] However, *price floors* have long been used as a tool of antitrust and regulatory policy to help limit the effects of any "market power" that a dominant firm possess.[22] This "decentralization strategy" relies on choosing the price floor that supports an efficient market outcome.

It is straightforward to determine the competitive market outcomes in this simple example. Let $\underline{p}_2$ denote the price floor that the PRC imposes on the Postal Service. Consider two cases:[23]

Case 1: $f > \underline{p}_2$. The market outcome would result in the Postal Service capturing the entire market for service 2 at a price (very, very) slightly below f, the unit cost of UPS.

Case 2: $f < \underline{p}_2$. The market outcome would result in UPS capturing the entire market at a price (very, very) slightly below $\underline{p}_2$, the lowest price that the Postal Service is permitted to charge.

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[21] See Baumol, Panzar, and Willig (1982). Proposition 11B.2, at p. 314 shows that only cost efficient industry configurations can be equilibria in perfectly contestable markets.

[22] See, for example, Viscusi, Harrington and Vernon (2005).

[23] For brevity, I omit the discussion of the (surprisingly complicated) unlikely case in which the price floor of the Postal Service *exactly* equals the unit cost of its competitor.

When Case 1 pertains, the market equilibrium result is the monopoly industry configuration, which yields total postal sector costs of $C(16,9) = 720$. It was shown above that this will be the least cost industry configuration whenever $f > 80$. Thus, the market outcome will be efficient whenever $\underline{p}_2 = 80$. Similarly, when Case 2 pertains, the market result is the mixed industry configuration, which yields total postal sector costs of $C(16,0) + 9f = 2880 + 9f$. Again, it was shown above, that this will be the least cost configuration whenever $f < 80$. Thus, the market outcome will always be efficient as long as $\underline{p}_2 = 80 = \underline{p}_{INC}$. This result is quite striking: *regardless of the value of the entrant's unit cost*, the competitive process will lead to the *efficient* market configuration as long as the price floor is set using the incremental cost test.

What would happen if the PRC imposed the higher price floor of $\underline{p}_{UPS} = 144$, as recommended in UPS Proposal One? There are 3 relevant ranges of UPS unit costs to consider: (a) $f > 144 = \underline{p}_{UPS}$; (b) $\underline{p}_{INC} = 80 < f < 144 = \underline{p}_{UPS}$; and (c) $f < 80 = \underline{p}_{INC}$. For UPS cost values in range (a), the market process continues to lead to the efficient outcome. The Postal Service would serve both markets, with the price in market two set (very, very) slightly below f. As derived above, total postal sector costs would be 3600. When UPS unit costs are in range (b), (i.e., greater than the incremental cost price floor of 80, but less than the UPS proposed price floor of 144), UPS would *inefficiently* capture the market, at a price (very, very) slightly below the UPS proposed price floor of 144. Total postal sector costs would be $2880 + 9f$, which is clearly greater than the 3600 that would result if both service were provided by the Postal Service: i.e., $2880 + 9f > 2880 + 9(80) = 3600 = C(16,9)$. Not only does UPS inefficiently capture the market, consumers end up paying a higher price (i.e., $144 > f$) for the service! Finally, when UPS's unit costs are actually below the Postal

Service's average incremental costs (i.e., $f < 80$), UPS *efficiently* captures the market, but at a price (very, very) slightly below 144. While total postal sector costs would be at the efficient level of $2880 + 9f < 3600$, customers of service 2 would pay a price of 144 instead of 80. The extra revenues translate directly into a windfall profit gain for UPS of $576 = (144 - 80)9$.

Table 1 summarizes the results of this example. The column headings refer to the three relevant ranges of UPS unit cost. The row headings refer to the market outcome of interest. In each square, the first entry is the outcome level that results using the Incremental Cost standard and the second entry is the outcome level that results under UPS Proposal One. Thus one sees that replacing the theoretically correct price floor based upon incremental costs with one calculated using UPS's proposed methodology cannot improve the competitive market outcome. At best, it will have no effect on postal sector efficiency or the price paid by consumers. At worst, it will lead to the rival *inefficiently* capturing the market and serving it an artificially high price. Even in those cases in which it is efficient for the rival to serve the market, the higher price floor imposed on the Postal Service lets the successful rival extract higher prices from consumers.

Table 1

UPS Cost (f) Outcome	$f < 80$	$80 < f < 144$	$144 < f$
Total Costs	$2880+9f$, $2880+9f$	3600, $2880+9f$	3600, 3600
Postal Service Profits	R_1-2880, R_1-2880	$R_1+9f-3600$, R_1-2880	$R_1+9f-3600$, $R_1+9f-3600$
UPS Profits	$9(80-f)$, $9(144-f)$	0, $9(144-f)$	0,0
Customer Payments	720, 1296	$9f$, 1296	$9f$, $9f$

7. Conclusions

Adoption of UPS Proposal One would violate the central premise of both incremental and marginal costs: the requirement that the costs attributed to the increment of output at issue be caused by that increment—in the sense that producing the increment would result in those costs, and not producing the increment would avoid them. Proposal One, by requiring the Postal Service to attribute *all* variable costs, including joint and common variable costs, to individual services, would have the effect of raising competitive product price floors above their theoretically correct levels. Thus, adopting UPS Proposal One would benefit UPS and other competitive carriers, but no one else.

To paraphrase Woody Hayes,[24] "three things can happen" when you raise the rate floor above the incremental cost standard, and the only possible beneficiaries are UPS and other private carriers. Consumers, the Postal Service and postal sector efficiency can only lose, they can never gain. The best possible result is no effect from the change.

[24] The legendary Ohio State football coach is widely reputed to have said: "Three things can happen when you pass the football, and two of them are *bad*."

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VERIFICATION

I, John C. Panzar, declare under penalty of perjury that the foregoing is true and correct. Executed on January 20, 2016.

EXHIBIT 1

University of Auckland
Standard

ACADEMIC CV

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NAME: **John C. Panzar**

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DEPARTMENT: **Economics**

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EDUCATIONAL QUALIFICATIONS:

1975 Stanford University, PhD., Economics
1973 Stanford University, A.M., Economics
1969 Carleton College, B.A., *cum laude* with Distinction in Economics

PREVIOUS APPOINTMENTS:

Louis W. Menk Professor, Emeritus; Northwestern University 2008-present
Professor of Economics, Northwestern University 1983-2008:
- Louis W. Menk Professor of Economics, 1988-2005
- Chairperson, Department of Economics, 1988-92
- Director of Graduate Studies, 1984-88; 1993-98
- William A. Patterson Distinguished Professor of Transportation 2000-01
- Acting Director, Northwestern University Transportation Center, 2000–01

Visiting positions:

- University of Auckland, 1998, 1999, 2004.
- Wissenschaftzentrum, Berlin: Summers 1995, 1996.
- Department of Economics, University of Pennsylvania: Spring 1983
- Department of Economics, UC Berkeley: Autumn, 1977
- San Francisco State University, Fall 1972

Research and Teaching Assistant, Stanford University 1970-74

SIGNIFICANT DISTINCTIONS / AWARDS:

Alumni Distinguished Achievement Award, Carleton College, June 1994.

PROFESSIONAL SOCIETIES / SERVICE / OTHER ACTIVITIES:

Memberships:
American Economic Association
European Association for Research in Industrial Economics (E.A.R.I.E.)
Econometric Society
International Industrial Organization Society
AEA Commission on Graduate Education in Economics, 1988-92
Board of Directors, Telecommunications Policy Research Conference: 1991-95, Chair 1994-95

Editorial Boards:

Review of Network Economics, Co-Editor 2002-
Journal of Regulatory Economics, Associate Editor 1988-
Journal of Economic Literature 1983-85
Journal of Information Economics and Policy 1982-
New Zealand Economic Papers 2007-

Program Committees:

8th Annual Telecommunications Policy Research Conference, 1979
Econometric Society, 1980 North American Winter Meetings.
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Econometric Society. 1985 World Congress.
American Economic Association, Annual Meetings 1987.
Econometric Society, 1991 North American Summer Meetings
Chair, 20th Annual Telecommunications Policy Research Conference, 1992

Referee for, inter alia:

National Science Foundation, *American Economic Review, Econometrica, Journal of Political Economy, Quarterly Journal of Economics, Bell Journal of Economics, Rand Journal of Economics, Journal of Economic Theory, International Economic Review, Journal of Industrial Economics, Journal of Economic Literature.*

TEACHING:

1998-2004	Co-Taught 782 – Special Topics: Regulation
2004	Co-Taught 381 – Foundations of Economic Analysis
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Summary Statement:

My research has focused on public policy toward network industries such as airlines, telecommunications, and postal service.

I have taught graduate and undergraduate courses in Industrial and Regulatory Economics for nearly 25 years. Many of my former graduate students have gone on to staff positions at the U. S. Department of Justice, the Federal Trade Commission, the Federal Communications Commission, the Illinois Commerce Commission, the New Zealand Commerce Commission and the Australian.

From 1974 to 1983 I was a Member of Technical Staff at Bell Telephone Laboratories (BTL). I was the Head of the Economic Analysis Research Department at BTL from 1980 to 1983. My duties at BTL involved conducting original research on the fundamental economic principles of regulatory pricing and costing analysis as well as consulting on regulatory and antitrust issues involving the Bell System. Along with my colleagues and co-authors, I helped to develop the economic concepts of economies of scope, multi-output economies of scale, monopoly sustainability, and contestable markets.

My published research includes books and numerous articles in major professional journals. Most of my publications are focused on pricing and costing issues facing multi-product network industries. The following are perhaps most notable. My co-authored monograph, *Contestable Markets and the Theory of Industry Structure*, provides the conceptual foundations for regulation of privatized network utilities. My chapter in the 1989 *Handbook of Industrial Organization*, "Theoretical Determinants of Firm and Industry Structure," provides the basis for cost analysis of multi-product enterprises such as telephone companies and other network operators.

Research Publications:

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U.S. Department of Transportation, "Transportation Deregulation and Safety," Co-Principal Investigator, 1987.

Northwestern University Annenberg Faculty Research Fellowship, 1987.

Northwestern University Ameritech Faculty Research Fellowship, 1990.

FAA, Center for Aviation Systems Reliability, Northwestern University Transportation Center, 1991-93.

Ameritech Foundation, "Consortium for Research on Telecommunications Policy." 1994-96.

Andrew Mellon Foundation, "Economics of the Scholarly Publishing Industry." Co-Principal Investigator, 1995-97.

Consultancy Projects:

Corporations:	Ameritech, AT&T, Bell Atlantic, Bell South, British Telecom, Commonwealth Edison, GT&E, Niagara Mohawk Power Company, Nynex, Pacific Telesis, Pitney Bowes, Inc., Southern California Gas, Southwestern Bell, Telephone and Data Systems, Telstra, Union Pacific RR, and U.S. West.
Industry Groups	American Newspaper Publishers Association, Electric Power Research Institute
Governmental	Canada Post, Deutsche Post AG, Deutsche Telekom AG, New Zealand Commerce Commission, U. S. Department of Transportation, U. S. Federal Trade Commission, U. S. Postal Rate Commission, U. S. Postal Service, Senate of the Commonwealth of Puerto Rico, OECD, World Bank, European Parliament.

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Bell Telephone Laboratories
Member of Technical Staff, 1974-1983.
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ANU	Arizona	Auckland	Barcelona
Bonn	Boston College	Cal Tech	Canterbury
Chalmers	Chicago	Cornell	Dartmouth
Duke	East Anglia	Hitsotubashi	Illinois
Indiana	INSEAD	Louvain	Lucca
Massey	Michigan	Michigan State	Montreal
Munich	Northern Illinois	Northwestern	NYU
Otago	Ohio State	Penn	Queens
Rice	Stanford	SUNY Binghampton	SUNY Stoneybrook
Texas	Texas A&M	Torino	Toronto
Toulouse	UC Berkeley	UCLA	UNSW
Vanderbilt	Virginia	Warwick	Wisconsin
Wyoming			

EXHIBIT 2

The Role of Costs for Postal Regulation

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1. **Introduction and Summary**

The purpose of this White Paper is to analyze the Cost and Revenue Analysis (CRA) costing framework developed by the Postal Service and its regulators over the past several decades with the objective of carefully explaining how various Postal Service cost measures can be used to guide the Postal Rate Commission (PRC) in fulfilling its pricing responsibilities, as specified in 39 U.S.C. 3622(c)(2) and 39 U.S.C. 3633(a). Essentially, these statutory provisions require that prices be set so that:

> (i) Each market dominant product bears the costs "attributable" to it through "reliably identified causal relationships."
>
> (ii) The market-dominant products of the Postal Service do not subsidize its competitive products.
>
> (iii) The competitive products, taken together, cover an "appropriate share of the institutional costs of the Postal Service."

Meeting this goal requires us to carefully explain how Postal Service cost concepts such as *volume variable costs*, *infra-marginal costs* and *institutional costs* are related to established economic cost concepts such as *marginal costs*, *incremental costs*, *fixed costs* and *variable costs*. Perhaps most importantly, we must determine the *economic* meaning of the statutory term

"attributable" and relate it to the concept of *attributable costs* as defined by the Postal Service in the CRA.

The paper presents a thorough discussion of the relevant multiproduct economic cost concepts, cost causality, and the workings of the CRA. However, the results of our analysis can be succinctly stated as follows:

(1) The statutory use of "attributable" clearly specifies that there be a *causal relationship* between the product provided and the costs attributed to it. Identifying the relevant economic cost condition is equally straightforward: the costs *caused* by a product (or group of products) are, by definition, the incremental costs of that product (or group of products). Therefore, statutory attributable costs should be interpreted as economic incremental costs. Thus, the PRC should use estimates of product incremental costs in order to meet the pricing responsibilities discussed above.

(2) The CRA methodology defines attributable costs in a way that only partially aligns with the economic definition of incremental costs. In general, CRA attributable costs understate economic incremental costs.

(3) Fortunately, the accounting data generated by the CRA can be used to calculate the economic incremental costs of Postal Service products.

Our conclusions are based upon more than two decades of economic research on postal costing methodology. Postal Service costing is designed to deal with the multiservice nature of postal operations. That is, it attempts to trace the impacts of specified service levels (volumes) on the levels of "cost drivers" required to meet them. It does so by specifying for each service a relationship between service volumes and driver activity for each of several cost components. Bradley, Colvin and Smith (1993) first explained the relationship between Postal Service costing relationships and economic concepts such as marginal cost. Subsequent work by Bradley,

Colvin and Panzar [(1997), (1999)] further explained how Postal Service cost accounts can be used to calculate the incremental cost of various services. This White Paper builds on this earlier work.

The remainder of this White Paper proceeds as follows. Section 2 provides a review of the economic multiproduct cost concepts required for our analysis.[1] Particular emphasis is placed upon the concept of incremental cost and its connection to cost causality. Section 3 presents a brief outline of the CRA costing methodology used by the Postal Service. Section 4 briefly reviews the cost concepts required to implement the pricing responsibilities of the PRC. In Section 5 we develop a simple example to illustrate the workings of the CRA. This framework allows us to clearly explain the relationships between postal constructs such as volume variable costs and attributable costs to standard economic cost measures. We further develop our example to illustrate how the data generated by the CRA can be used to inform economic policy issues related to pricing and cross-subsidization. Our final section offers a brief Conclusion.

2. Multiproduct Cost Functions and Cost Causality

To an economist, there is a *causal relationship* between the quantities of various economic goods and services provided and the expenditures incurred by the entity producing those goods and services. In economic textbooks, this relationship is usually defined as the solution to an explicit optimization problem: i.e., it is assumed that the amount of inputs chosen by the firm, $\mathbf{x} = (x_1, x_2, \ldots, x_m)$, are chosen so as to minimize the total expenditures required to

[1] The reader is referred to Baumol, Panzar and Willig (1988) and Panzar (1989) for more detailed discussions.

produce a vector of specified output levels, $\mathbf{Q} = (Q_1, Q_2, \ldots, Q_n)$.[2] However, for purposes of the present discussion, it is only necessary that there exists a relatively stable relationship between inputs, outputs and factor prices so that one can assume that there exists a multiproduct Postal Service *behavioral cost function*, $C: \mathbb{R}_+^n \times \mathbb{R}_{++}^m \rightarrow \mathbb{R}_+$, relating the levels of services provided and input prices to the resulting amount of costs incurred.[3] In what follows, we will assume that the factor prices facing the Postal Service are exogenously fixed, so that the relationships of interest can be summarized by the function $C(\mathbf{Q})$. We also assume that the cost relationships under discussion are (what economists refer to as) *long-run* costs.[4]

We will make extensive use of the following standard economic cost concepts and basic definitions:

Definition E1: *TOTAL COSTS*. The function $C(\mathbf{Q})$ measures the total costs caused by the production of the specified quantities of *all* products produced by the firm. Total Costs are causally related to the output vector $\mathbf{Q}$, because they would *all* vanish if $\mathbf{Q}$ did.

[2] More formally, let the vectors $\mathbf{Q} \in \mathbb{R}_+^n$ and $\mathbf{x} \in \mathbb{R}_+^m$, respectively, denote output levels of the various goods and services offered by the firm and the quantities of the inputs used to produce them and let $\mathbf{w} \in \mathbb{R}_{++}^m$ denote the vector of positive input prices facing the firm. Then, the solution to the firm's cost minimization problem defines the minimum cost function $\tilde{C}: \mathbb{R}_+^n \times \mathbb{R}_{++}^m \rightarrow \mathbb{R}_+$ as $\tilde{C}(\mathbf{Q}, \mathbf{w}) = \min_{\mathbf{x}}\{\mathbf{wx} : \mathbf{Q} \text{ can be produced from } \mathbf{x}\}$. See, for example, the treatments in an advanced microeconomic textbook such as Mas-Colell, Whinston and Green (1995).

[3] In testimony before the Commission, Panzar (1997) has described in some detail how such a behavioral cost function can be viewed as the result of the implementation by the Postal Service of a well-specified (although not necessarily cost-minimizing) Operating Plan.

[4] Long-run costs are sometimes referred to as "drawing board costs." They are the expenditures that would be incurred to provide the specified vector of output quantities if the firm were able to "start from scratch," not burdened by legacy facilities or labor contracts.

This cost function is assumed to be defined for *any* nonnegative output vector $\mathbf{Q} \geq \mathbf{0}$. However, it is customary to use a special terminology for the costs associated with output vectors in which one or more output levels are equal to zero. A bit of additional notation is needed to define total costs for proper subsets of products. Given any reference output vector $\mathbf{Q} > \mathbf{0}$ in which all n products are produced in strictly positive quantity, let $\mathbf{Q}_S$ denote that vector whose ith component is equal to that of the reference vector $\mathbf{Q}$ for $i \in S$ and equal to 0 for $i \notin S$. Thus, $\mathbf{Q} = \mathbf{Q}_S + \mathbf{Q}_{N/S}$, where the set $N/S \equiv \{i \in N \mid i \notin S\}$ is the *complement* of S in N. We are now able to state:

Definition E2. *STAND ALONE COSTS*. The stand alone costs of any product set $S \subset N$ and its complement N/S are given by $C(\mathbf{Q}_S)$ and $C(\mathbf{Q}_{N/S})$, respectively. Stand alone costs are jointly *caused* by *all* of the products in the subset in question.

The important economic implications of C are contained in a complete description of how costs change in response to a change in the levels of the services provided. Economists refer to these cost changes as:

Definition E3. *INCREMENTAL COSTS*. The incremental costs of any vector of changes in output levels or volumes, $\Delta\mathbf{Q} = (\Delta Q_1, \Delta Q_2, \ldots, \Delta Q_n)$, relative to a base vector $\mathbf{Q}^0$ of total output is the amount of costs that would be *avoided* if $\Delta\mathbf{Q}$ were no longer produced. That is, $IC(\mathbf{Q}^0;\Delta\mathbf{Q}) = C(\mathbf{Q}^0) - C(\mathbf{Q}^0 - \Delta\mathbf{Q})$. Incremental costs are jointly *caused* by *all* of the changes in *all* of the products involved in $\Delta\mathbf{Q}$.

Other familiar cost concepts can be constructed from this definition through artful choices of the increment, $\Delta\mathbf{Q}$. (Unless otherwise specified, the base vector, $\mathbf{Q}^0$, is taken to be the total output vector $\mathbf{Q}$.) For example, the *marginal cost of service i*, $MC_i(\mathbf{Q})$, results from choosing the increment $\Delta\mathbf{Q} = (0, 0, \ldots, \Delta Q_i, \ldots, 0)$ and taking the limit of $IC/\Delta Q_i$ as ΔQ_i goes to zero. The incremental cost of a particular product or service, say service i, IC_i, is obtained by choosing the increment to be *all* units of that service (and *only* that service). In that case, we assume that $\Delta\mathbf{Q} = (0, 0, Q_i, \ldots, 0)$ so that $IC_i = C(\mathbf{Q}) - C(\mathbf{Q}_{N/i})$. Similarly, the incremental cost

of a set of services $S \subset N$ results from choosing the increment $\Delta\mathbf{Q} = \mathbf{Q}_S$. Thus, $IC_S(\mathbf{Q}) = C(\mathbf{Q}) - C(\mathbf{Q}_{N/S}) = C(\mathbf{Q}_S + \mathbf{Q}_{N/S}) - C(\mathbf{Q}_{N/S})$.

The economic concept of incremental costs is central to any notion of *cost causality*. To say that service (or group of services) *X causes* an expenditure *Y* is *equivalent* to saying that *Y* is the Incremental Cost of *X*. Regulatory statues do not always explicitly refer to the above, *economic definition*, of Incremental Cost. However, most statutes are explicitly concerned with the concept of *cost causality*, using the term much as an economist would. One of the clearest (and most succinct) definitions we have come across is due to the Illinois Commerce Commission

(**Title 83, Section 791.30, Cost Causation Principle**):

> *Costs shall be attributed to individual services or groups of services based on the following cost causation principle. Costs are recognized as being caused by a service or group of services if:*
>
> *a*) *The costs are brought into existence as a direct result of providing the service or group of services; or*
>
> *b*) *The costs are avoided if the service or group of services is not provided.*

The parallel emphasis on the concept of *avoided cost* is particularly important as a guide to intuition. Since costs are frequently "brought into existence" by a number of different products or services, it is possible to get caught up in a "chicken and egg" confusion based upon hypothetical scenarios concerning the *order* in which products were introduced into the firm's portfolio. Indeed, the costs of *adding* a particular product (or group of products) will differ depending upon the mix of products already present. However, it is unambiguously clear that the only *added costs* that are equal to *avoided cost* are those that result when the product (or group of products) in question is added *last*. And, that is precisely the cost measured by the economic definition of Incremental Costs, as presented in Definition E3.

Finally, economists often find it necessary to distinguish between variable costs that vary *continuously* with volume and fixed costs that do not. To make this distinction it is useful to assume that our basic cost function $C(\mathbf{Q})$ can be rewritten as follows:

$$C(\mathbf{Q}) = F\{S\} + V(\mathbf{Q}) \qquad (1)$$

Here, the function $V\colon \mathbb{R}_+^n \to \mathbb{R}_+$ is usually assumed to be increasing and twice continuously differentiable, with $V(\mathbf{0}) = 0$. Let the set $S \subseteq N$ denote that subset of services that are produced in *strictly positive* quantities. That is, $S = \{i \in N\colon Q_i > 0\}$. Define the "fixed cost function" $F\colon 2^N \to \mathbb{R}_+$ to have the following intuitive properties. First, long-run fixed costs are zero when there are *no* services provided: i.e., $F\{\emptyset\} = 0$. Second, the level of fixed costs increases as the set of services offered includes more and more products: i.e., $F\{T\} \leq F\{T'\} \leq F\{N\}$ for $T \supseteq T' \supseteq N$. We can now formally state the following definitions:

Definition E4. *VARIABLE COSTS*. The function $V(\mathbf{Q})$ measures the variable costs of the firm: i.e., those costs that vary continuously with volume.

Definition E5. *FIXED COSTS*. The fixed costs of the firm are those that must be (discontinuously) incurred as *any* positive amount of output is produced. (That is why fixed costs are sometimes referred to as "start up costs.") The function $F\{S\}$ allows the amount of the start-up costs to vary with the set $S \subseteq N$ of products introduced.

The division of costs into "fixed" and "variable" categories can be carried over to any of the cost concepts defined above. For example, the *fixed portion* of the Incremental Cost of product *i* is given by $F\{N\} - F\{N/i\}$, the difference between the amount of fixed costs that arise when all products are produced and the amount of fixed costs that remain when the production of product *i* is discontinued. The *variable portion* of the Incremental Cost of product *i* is similarly defined using the variable cost function: i.e., $V(\mathbf{Q}) - V(\mathbf{Q}_{N/i})$.[5] Thus, the basic formula for the total incremental cost of product *i* can always be rewritten as the sum of its fixed and variable portions:

[5] The expressions for the fixed and variable portions of the incremental costs associated with subsets of products are similar. These are, respectively, given by $F\{N\} - F\{N/S\}$ and $V(\mathbf{Q}) - V(\mathbf{Q}_{N/S})$.

$$IC_i = [F\{N\} + V(\mathbf{Q})] - \left[F\{N/i\} + V\left(\mathbf{Q}_{N/i}\right)\right] = [F\{N\} - F\{N/i\}] + [V(\mathbf{Q}) - V\left(\mathbf{Q}_{N/i}\right)] \quad (2)$$

A brief digression on the nature of the fixed costs discussed in our analysis is necessary. As noted earlier, our discussion is devoted entirely to the case of long-run costs. Yet, some readers may recall (perhaps from a course in Introductory Economics) seeing the maxim: "Fixed costs are zero in the long-run." That maxim reflects the fact that, when all input levels can be freely adjusted (i.e., the *economist's* long-run), the cost of producing nothing must, by definition, *be* nothing. That is, $C(\mathbf{0}) = 0$. Nothing here contradicts that basic tautology. The fixed costs considered here could perhaps more descriptively be referred to as "start-up costs" that measure the size of "jump discontinuities at the origin." These are the significant levels of costs that must be incurred in order to produce even a vanishingly small level of output.[6]

3. Brief Review of Postal Service Costing (CRA)

The Postal Service employs a product costing methodology to generate cost information, both for internal decision making and to satisfying the cost reporting requirements of the PRC. This costing system is referred to as Cost and Revenue Analysis (CRA).[7] The CRA models total costs by dividing the incurred expenses of the enterprise into some number of *cost components*, indexed by $j = 1, \ldots, J$. The expenditures associated with the jth cost component, C^j, are

[6] Think of a railroad-building project at the "drawing board stage." The planned costs to produce *zero* output – walking away from the project – would indeed be zero. However, if the plans called for the production of a very, very small level of output, say one-ton mile of A to B transportation, the planned costs would *not* be "close" to zero. They would include millions of dollars to purchase the right of way, prepare the roadbed, lay the track, etc. This is the kind of situation economists have in mind when referring to the presence of "fixed costs" in the "long-run."

[7] See Bradley, Colvin and Smith (1993) and RARC (2012a) for a detailed description of Postal Service costing methodology, as reflected in its Cost and Revenue Analysis (CRA) reports. Here, we present only a basic description of the CRA in order to illustrate the issues at hand.

assumed to be caused by the level of the *cost driver*, D^j, associated with that activity: that is, $C^j = C^j(D^j)$. Let $MC^j = dC^j/dD^j$ denote the marginal cost of component *j*, the increase in component cost caused by a marginal increase in component driver activity. The level of the cost driver is determined by the volumes of individual mail products $D^j = D^j(\mathbf{Q})$.

Thus, the CRA analyzes Postal Service cost by characterizing the behavior of component costs with respect to their cost drivers and then *distributing* the resulting cost pools to individual products based upon their impacts on the level of driver activity. For example, one important component of postal costs is transportation costs. On a particular route, transportation costs are primarily determined by the total volume, in cubic inches, of all mail products transported. The component costs are then specified as a function of the number of cubic inches transported. Thus, for transportation costs, the number of cubic inches is the level of cost driver activity. The total number of cubic inches required for transportation is determined by the number of cubic inches per piece of each type of mail product and the number of pieces of each type transported.

3.1 Volume Variability of Cost Components

The CRA analysis begins by determining the proportion of component costs that are "volume variable" with respect to the level of the cost driver. In postal parlance, this is done by applying a "variability factor" to total component costs. In economic terms, this variability factor is simply the elasticity, $\eta^j(D^j)$, of total component costs with respect to component driver activity. This elasticity is defined as the percentage change in total component costs divided by the percentage change in driver activity:

$$\eta^j(D^j) \equiv \frac{\frac{dC^j}{C^j}}{\frac{dD^j}{D^j}} = \frac{D^j}{C^j}\frac{dC^j}{dD^j} = \frac{D^j MC^j}{C^j} \qquad (3)$$

The volume variable costs of component *j*, VVC^j, are then obtained by multiplying total component costs by the variability factor:

$$VVC^j = C^j\eta^j = C^j\left[\frac{D^jMC^j}{C^j}\right] = D^jMC^j(D^j) \quad (4)$$

This process is essentially a method of reflecting the *economies of scale* associated with a particular cost component. If component costs rise less than proportionately with driver activity ($\eta^j < 1$), an economist would say that the component was characterized by increasing returns to scale. A postal analyst would say that the component's volume variability was less than 100%.

Definition P1: *COMPONENT VOLUME VARIABLE COSTS*. The volume variable costs associated with a cost component are equal to the elasticity of component cost with respect to driver activity multiplied by total component costs.

It is important to emphasize that volume variable costs are *not* equivalent to the economic concept of variable costs, defined above. In order to clarify this issue, it is useful to rewrite total component costs as the sum of its fixed and variable components:

$$C^j\left(D^j\right) = F^j + V^j\left(D^j\right) \quad (5)$$

Here, component fixed costs, F^j, and component variable costs, $V^j(D^j)$, correspond exactly to the economic concepts presented in Definitions E4 and E5. Component fixed costs are "start-up" costs that must be incurred to provide even an arbitrarily small level of driver activity. Component variable costs consist of those component expenditures that vary continuously with the level of driver activity. Differentiating equation (5) with respect to D^j yields $MC^j = MV^j$, the condition that marginal component cost equals marginal variable component costs. This allows us to rewrite equation (2) as

$$VVC^j = D^jMC^j(D^j) = D^jMV^j(D^j) \quad (6)$$

Therefore, the difference between *postal* component volume variable costs and the *economic* concept of component variable costs is given by $V(D^j) - D^j MV^j(D^j)$. Only in the case of constant component marginal costs will this difference be zero. Component volume variable costs will always be less than component variable costs whenever component *average* variable costs are decreasing (and, hence, greater than component marginal cost).

As we shall see, defining volume variable costs at the component level is a very useful step toward obtaining estimates of marginal cost from cost accounting data. However, it creates another category of costs, i.e., component infra-marginal costs, IMC^j, requiring specialized postal terminology:

Definition P2: *COMPONENT INFRA-MARGINAL COSTS*. The infra-marginal costs associated with a cost component are equal to component variable costs *minus* component volume variable costs. That is, $IMC^j(D^j) = V^j(D^j) - D^j MV^j(D^j) = V^j(D^j) - VVC^j(D^j)$.

Infra-marginal costs are *not* a standard economic cost concept. Essentially, they are defined by what they *are not*: i.e., they are variable costs that are *not* volume variable costs.

3.2 Distribution of Component Costs to Individual Postal Products

After the component volume variable costs are determined, they are assigned, or *distributed*, to individual products based upon a specified relationship between product volumes and the level of component driver activity. The level of the cost driver is assumed to be determined by the volumes of individual mail products; i.e., $D^j = D^j(\mathbf{Q})$. Cost drivers are typically defined in such a way that the functions D^j are *linearly homogeneous*, so that a proportional increase in all volumes leads to an increase of driver activity of the same proportion: i.e., $D^j(t\mathbf{Q}) = tD^j(\mathbf{Q})$ for any constant $t > 0$. Often, the relationship is assumed to be linear, so that $D^j(\mathbf{Q}) = \mathbf{mQ} = \sum_i m_i Q_i$ for some vector of product weights $\mathbf{m} = (m_1, \ldots, m_n)$. For

example, suppose that cubic inches are recognized as the cost driver for the transportation cost component and that there are two services "letters" and "parcels." If each letter occupies m_l cubic inches and each parcel m_p cubic inches, the total amount of the cubic inches cost driver is given by: $D^{cube} = m_l Q_l + m_p Q_p$.

The next step is to determine each product's share, $s_i^j(\mathbf{Q})$, of the cost driver activity of component *j*. When possible, this share is simply the estimated elasticity of component *j* driver activity with respect to the volume of product *i*. That is,

$$s_i^j = \frac{Q_i}{D^j}\frac{\partial D^j(\mathbf{Q})}{\partial Q_i} \tag{7}$$

(By Euler's Theorem, the linear homogeneity of $D^j(\mathbf{Q})$ ensures that these shares sum to one.) In practice, most of the driver relationships are assumed to be linear. The result is that each product's share is simply its (weighted) contribution to a (weighted) sum of outputs:

$$s_i^j = \frac{Q_i}{D^j}\frac{\partial D^j(\mathbf{Q})}{\partial Q_i} = \frac{Q_i m_i}{\sum_i Q_i m_i} \tag{8}$$

The determination of driver shares for a cost component makes it possible to *distribute* any portion of the component's cost to individual services.[8] In the CRA, only a component's volume variable costs are distributed to individual products.[9] The amount of component *j* volume variable cost distributed to product *i* is given by:

[8] Indeed, the vector of driver shares is sometimes referred to as a *distribution key*.

[9] However, in principle, the same driver shares can be used to distribute *any* category of component costs: e.g., fixed costs, variable costs and infra-marginal costs.

$$VVC_i^j = s_i^j VVC^j = s_i^j C^j \eta^j = C^j \left[\frac{Q_i}{D^j}\frac{\partial D^j}{\partial Q_i}\right]\left[\frac{D^j}{C^j}MC^j\right] = Q_i MC^j \frac{\partial D^j}{\partial Q_i} \quad (9)$$

However, it is important to avoid the temptation to view the volume variable costs *distributed* to a particular product as being *caused* by that product. The variable costs of a component are *jointly* caused by *all* the volumes of *all* the products that utilize that component. These costs may be *distributed* to individual products based on that product's share of driver activity. However, unless component marginal cost is constant, the resulting cost distribution to product *i* is *not* the amount of cost that would be *avoided* if product *i* were to be discontinued: i.e., it is not the incremental cost of product *i*.

The *total* amount of volume variable cost attributed to any product *i* is determined by summing its component volume variable costs distributions over all cost components:

$$VVC_i = \sum_j VVC_i^j = Q_i \sum_j MC^j \frac{\partial D_j}{\partial Q_i} \quad (10)$$

The CRA expresses the volume variable costs distributed to service *i* on a per unit basis by dividing VVC_i by the volume of service *i*. That is,

$$u_i(\boldsymbol{Q}) = \frac{VVC_i}{Q_i} = \sum_j MC^j \frac{\partial D_j}{\partial Q_i} = \frac{\partial[\sum_j C^j[D_j(\mathbf{Q})]}{\partial Q_i} \equiv MC_i(\mathbf{Q}) \quad (11)$$

The well-known[10] outcome of the CRA's volume variability analysis is the surprising result that the unit volume variable cost of a service is equal to the marginal cost of that service.

The end result of the CRA process is the determination of the *attributable costs*, A_i, of each individual postal product. This is obtained by adding any specific-fixed costs,[11] F_i,

[10] See, for example, Bradley, Colvin and Smith (1993) and Bradley, Colvin and Panzar (1999).

associated with the product to the product's volume variable costs. This gives rise to another specialized postal cost term:

Definition P3: *ATTRIBUTABLE COSTS*. The attributable costs of product *i* are equal to the sum of that product's specific-fixed costs and its volume variable costs: i.e., $A_i = F_i + VVC_i$.

4. Economic Cost Concepts, "Postal" Cost Concepts and the Pricing Responsibilities of the Postal Regulatory Commission.

From an economic policy perspective, the primary purpose of a firm's costing system is to provide estimates of the marginal and incremental costs of the products sold by the firm.

4.1 Unit Volume Variable Costs are designed to measure Economic Marginal Costs

Marginal costs are an essential ingredient in the pursuit of any policy objective for the firm. Regardless of the objective of the firm or its regulator, appropriate pricing policy must be based upon reliable estimates of each product's marginal cost. [12] Fortunately, the costing methodology developed in the CRA is exceptionally well designed to provide the Commission

[11] Interestingly, this is one case in which postal cost terminology coincides with standard economic usage. Compare, for example, Bradley, Colvin and Smith (1993) and Panzar (1989). Specific-fixed costs are start-up costs that arise when any positive amount of the service is provided. And, of course, these costs are avoided if the service is discontinued. Specific-fixed costs do not vary with the product volume or the level of driver activity of any component. The CRA typically assumes that specific-fixed costs are independent and additive. Thus, in terms of equation (1) and Definition E5, we adopted the notation that $F_i = F\{i\}$ and $F\{S\} = F_S = \Sigma_{i \in S} F_i$.

[12] The efficiencies associated with marginal cost pricing are a major topic of modern microeconomic theory, and need no elaboration here. Of course, marginal cost pricing would result in losses for enterprises operating under increasing returns to scale (such as the Postal Service). However, even in these cases, *economically rational* pricing policies must utilize information on marginal costs. See, for example, the discussions in Viscusi, Harrington and Vernon (2005) and Braeutigam (1989).

with accurate and detailed estimates of the marginal costs of Postal Service products. As explained in the previous section, the CRA magnitude, *unit volume variable cost*, corresponds exactly to the economic definition of marginal costs. Thus, the CRA's "volume variability approach" to costing provides accurate measures of marginal cost on a product by product basis. In addition, this framework is especially useful for evaluating the profitability of product offerings, such as Negotiated Service Agreements, that involve only small percentage changes in Postal Service volumes.[13]

4.2 Product-level CRA Attributable Costs are *not* designed to measure product level Incremental Costs.

For the economist, the second role of cost analysis is to make it possible for prices to be evaluated for cross-subsidization. It is now standard in the regulatory economics literature that avoiding cross-subsidization means that the customers of each product (or group of products) pay more to the firm in revenues than the incremental cost of said product (or group of products).[14] However, even today, not all regulatory statutes address cross-subsidy concerns through explicit reference to the above-mentioned "incremental cost test." Rather, they may use language to the effect that revenues obtained from a product are such that

> " … each class of mail or type of mail service bear the direct and indirect postal costs attributable to each class or type of mail service through reliably identified causal relationships …"

[13] See the analysis in RARC (2012b).

[14] Again, see Viscusi, Harrington and Vernon (2005) or Braeutigam (1989).

The term "attributable" is commonly used in regulatory statues, but it has no precise economic definition. However, as explained in Section 2, costs resulting from "causal relationships" can only be measured as incremental costs.

Unfortunately, the attributable cost of a product, as developed by the CRA does not adequately measure that product's incremental cost. One portion of attributable cost, specific-fixed cost, makes up precisely the fixed part of a product's incremental cost. These are clearly *causal*, since they would be avoided if the product were not produced. The difficulty is with the notion of product-level volume variable costs. These are, in general, *not* equal to the variable portion of a product's economic incremental costs. The reason that a product's CRA volume variable costs are *not* generally equal to the costs that would be avoided if the product were eliminated is quite intuitive. Essentially, the reason is that the CRA's volume variability approach takes the product's economic marginal cost – which is, indeed, the avoided cost of the *last* unit of output – and applies that amount to *all* the units of the product provided. But, these infra-marginal units will not have the same amount of avoided costs associated with them unless marginal costs are constant. The analysis of the next section explains this point in detail.

5. Volume Variable Costs, Incremental Costs and Infra-Marginal Costs in the CRA: an Illustrative Example.

In this section we explain the distinction between volume variable costs, incremental costs and infra-marginal costs using a simplified CRA – type model in which there are *n* services, $i \in \{1,2,\dots,n\} = N$, and only one cost component. This example generally reflects the CRA framework, but greatly simplifies the discussion (and mathematical notation). Treating the case of a single cost component is, surprisingly, not particularly restrictive because most CRA analysis and computations takes place at the component level. The results are then aggregated.

The empirical analysis in our Task 2 Report applies the insights developed here to the products and cost components used by the Postal Service.

The expenses incurred by any cost component are *caused* by the level of driver activity, D, according to the formula:

$$C(D) = F + v(D) \tag{12}$$

Here, $v(D)$ denotes *component variable costs*, that portion of component costs that varies directly with the level of cost driver activity. F denotes the level of any *component fixed costs*. These are component costs that do not vary with the amount of driver activity (or with the volumes of individual services). Our stylized CRA formulation also allows for the possibility that there may be *specific-fixed costs* F_i. These costs do not vary with service volumes (or the level of driver activity). However, they would disappear if the service in question were to be discontinued. The level of driver activity, itself, determined by service level volumes, Q_i. As discussed in the previous section, the relationship $D(\mathbf{Q})$ is usually assumed to be linear. For notational simplicity, we will assume that the units in which service volumes are measured are chosen so that all the weights m_i are equal to one and $D = Q_1 + Q_2 + \ldots + Q_n = Q$.

It is now possible to express the costs of our stylized postal operator in terms of the standard multiproduct cost function used by economists:

$$C(\mathbf{Q}) = C(Q_1 + Q_2 + \ldots + Q_n) = C(Q) = \sum_{i \in N} F_i + F + v(Q) \tag{13}$$

As usual, total costs can be divided into two categories. *Fixed costs* are the sum of component fixed cost and the various specific-fixed costs: $F + F_1 + F_2 + \ldots + F_n$. In this example, the only costs that vary with volume are the *component variable costs*, v.

It is also possible to derive formulae for the standard economic cost concepts of (product) *marginal costs* and (product) *incremental costs* for this example:

$$MC_i = \frac{\partial C}{\partial Q_i} = v'(Q)\frac{\partial Q}{\partial Q_i} = v'(Q) \text{ for all } i \in N \quad (14)$$

$$IC_i = C(Q) - C(Q - Q_i) = F_i + v(Q) - v(Q - Q_i) = F_i + \int_{Q-Q_i}^{Q} v'(q)dq \text{ for } i \in N \quad (15)$$

It may also be necessary to consider the incremental costs associated with groups of products: i.e., the product subsets $S \subset N$. These are given by the following formula:

$$IC_S = \sum_{i \in S} F_i + v(Q - \sum_{i \in S} Q_i) \equiv F_S + v(Q - Q_S) \quad (16)$$

These are all the cost measures an economist would need to set prices and test for cross-subsidization. Notice that terms commonly used in postal costing discussions, such as *attributable costs*, *volume variable costs*, and *infra-marginal costs* do not arise.

Next, we apply CRA costing methodology to our example. The central feature of the CRA approach is the concept of *volume variable cost*, *VVC*. Again, it is important to point out that, despite its name, *VVC* is *not* equivalent to the economic concept of variable costs. Rather, the volume variable costs of a component are determined by applying a *variability factor*, η, to total component costs. This factor is obtained by estimating (econometrically or otherwise) the elasticity of *total* component costs with respect to the level of cost driver activity. For the present example, we have:

$$\eta = \frac{D}{c(D)}\frac{dc}{dD} = \frac{Dc\prime(D)}{c(D)} = \frac{Dv\prime(D)}{F+v(D)} \quad (17)$$

and

$$VVC = \eta c(D) = Dc'(D) = Dv'(D) = Qv'(Q) \quad (18)$$

The nature of these postal cost concepts is illustrated in Figure 1, adapted from Bradley, Colvin, and Smith (1993). The quantity of the cost driver is measured on the horizontal axis and total component cost is measured on the vertical axis. Total component cost associated with quantity 0*D* of the cost driver is given by the distance 0*E*. The distance 0*A* represents the component's fixed cost. Constructing the tangent to the cost function at *D*, and extending it to the vertical axis at point *B*, provides a measure of volume variable costs for this component. These are given by the distance *BE*, which is equal to marginal component cost times the quantity of the cost driver. Whenever marginal costs are a declining function of the level of the cost driver, a component's volume variable costs will be less than its total variable costs (*AE*).

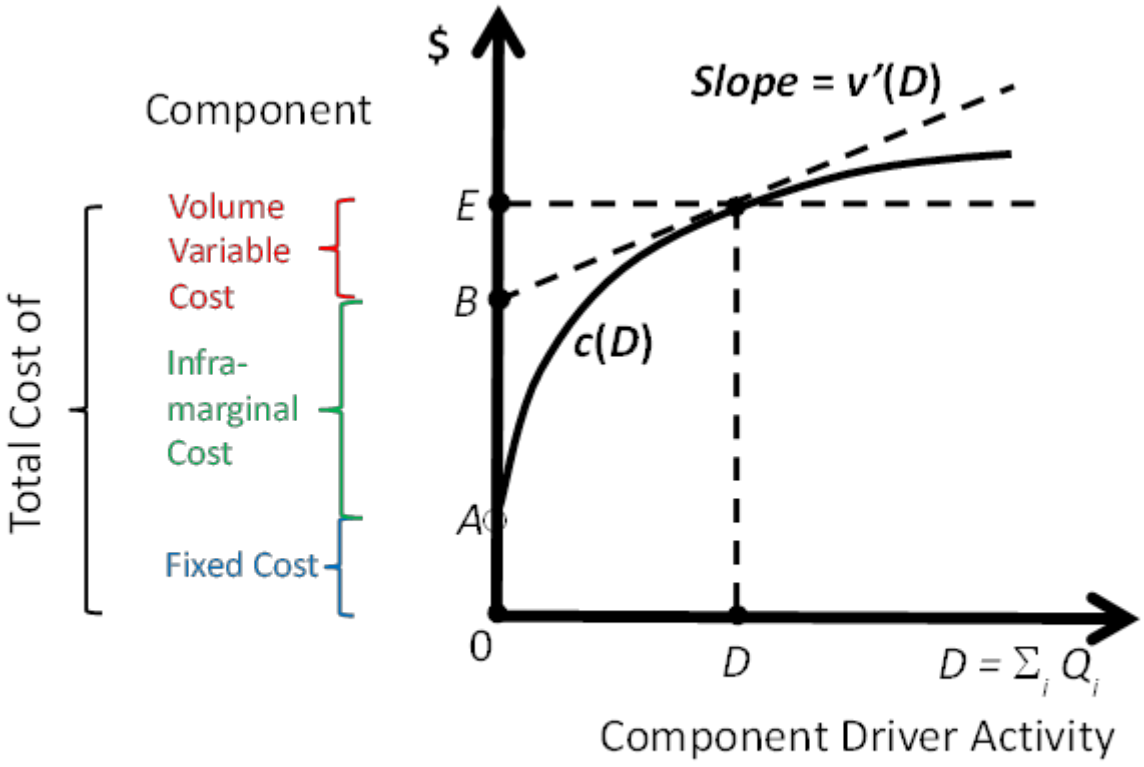

FIGURE 1

As explained above, "infra-marginal cost" is not a standard term in economic analysis. In the postal costing literature,[15] infra-marginal costs have ended up being defined in terms of what they *are not*: i.e., volume variable costs. Thus, infra-marginal costs are that portion of component variable costs that are not volume variable costs. In Figure 1, infra-marginal costs for this component are given by the distance A*B*. That is, the difference between total component variable costs *AE* and component Volume Variable Costs *BE*.

Of course prices are set for *products*, not cost drivers. Thus it is necessary to distribute the total expenses of each cost component to the individual products of the enterprise. As described above, this requires a specification of the relationship between the levels of service volumes and the level of cost driver activity. In practice, this specification is often linear. In our illustrative example the weights are equal to one, so that the level of driver activity is equal to the simple sum of the service volumes: i.e., $D = Q_1 + Q_2 + \ldots + Q_n = Q$. Then, the portion of volume variable costs that the CRA would *distribute* to each product is given by:

$$VVC_i = \frac{Q_i}{Q} VVC = Q_i v'(Q) \quad i \in N \tag{19}$$

As noted earlier, at the product level, per unit volume variable cost is precisely equal to marginal cost:

$$u_i(Q) \equiv \frac{VVC_i}{Q_i} = v'(Q) = MC_i(Q) \tag{20}$$

[15] See, for example, Bradley, Colvin and Panzar (1999).

Unfortunately, the postal costing process does not fully exploit this equivalence. Instead, the CRA proceeds by adding a product's specific fixed cost to its (distributed) volume variable cost to obtain the product's total *attributable cost*:

$$A_i = VVC_i + F_i \tag{21}$$

Dividing by service volume yields a measure of *per unit attributable cost*:

$$a_i = \frac{A_i}{Q_i} = v'(Q) + \frac{F_i}{Q_i} = MC_i(Q) + \frac{F_i}{Q_i} \tag{22}$$

As is clear from the above discussion, a_i differs from an economically valid measure of marginal cost because it averages specific-fixed costs over service volume. Thus it is not a suitable substitute for marginal cost for policy purposes. (Fortunately, the routinely calculated unit volume variable cost *is* an accurate measure of marginal cost.)

Next, we explain why attributable cost is not an appropriate substitute for *incremental cost*, the primary tool for determining whether prices are free of cross-subsidization. To see this, subtract the above expression for attributable cost from that for the incremental cost of product *i*:

$$IC_i - A_i = [F_i + v(Q) - v(Q - Q_i)] - [F_i + Q_i v'(Q)] = \int_{Q-Q_i}^{Q} [v'(q) - v'(Q)]dq > 0 \tag{21}$$

The inequality follows from the fact that marginal component cost is decreasing. This means that $v'(Q) < v'(q)$ for all $q < Q$. Perhaps a more useful way to look at this result is as follows:

$$IC_i = A_i + [v(Q) - v(Q - Q_i)] - Q_i v'(Q) = A_i + \int_{Q-Q_i}^{Q} [v'(q) - v'(Q)]dq > A_i \tag{22}$$

The result can be seen more easily using Figure 2. Again, the level of driver activity is measured along the horizontal axis. Now, the vertical axis measures the level of marginal

component cost v'. Two driver levels and the associated marginal costs are of interest: (i) the level of marginal cost, $v'(Q)$, evaluated at the total level of component driver activity when all products are provided; and (ii) the level of marginal cost, $v'(Q - Q_i)$, that would result if service *i* and its driver activity Q_i were no longer provided. To simplify notation in the diagram, denote the total amount of component driver activity that would occur *without* that caused by service *i* by $Q_{-i} = Q - Q_i$.

Recall that the volume variable cost for service *i* are given by $v'(Q)Q_i$. This is the rectangular area $Q_{-i}QFE$. The variable portion of the incremental cost of service *i* is the difference between the total variable cost $v(Q)$ less the variable cost $v(Q_{-i})$ that would be incurred if service *i* were not produced. Total variable component cost is, by definition, the area under the component marginal cost curve up to Q, the level of *total* driver activity. Total variable component cost *without* product *i* is the area under the component marginal cost up to Q_{-i}, the level of driver activity that would pertain *without* that due to product *i*. The variable portion of incremental cost of product *i* for the component is the difference between the two: i.e., the area $Q_{-i}QFB$ under the component marginal cost curve between Q_{-i} and Q. Finally, since the fixed portions of attributable costs and incremental costs are identical (and equal to F_i), they cancel out. The area *BEF* is difference between the variable portion of product *i*'s incremental cost and its volume variable cost.

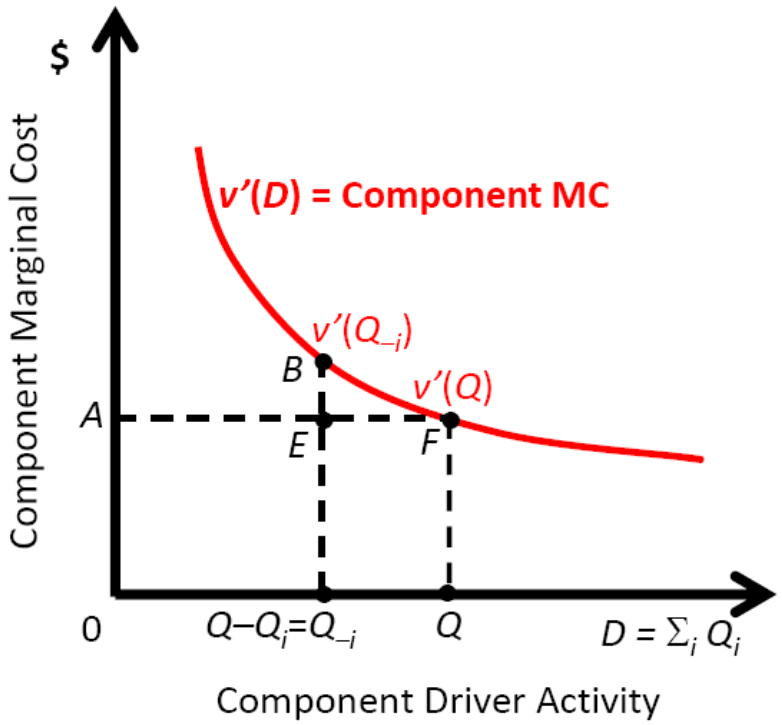

FIGURE 2

However, for plausible parameter values, it turns out that this difference is not large. In the case in which component variable costs take on the constant elasticity form, the difference between incremental costs and attributable costs is given by:

$$IC_i - A_i = F_i + [AQ^{\varepsilon} - A(Q - Q_i)^{\varepsilon}] - F_i - Q_i \varepsilon A Q^{\varepsilon - 1} = AQ^{\varepsilon}[1 - (1 - s_i)^{\varepsilon} - \varepsilon s_i] \qquad (23)$$

or,

$$IC_i = A_i + Q_i \varepsilon A Q^{\varepsilon - 1} - [AQ^{\varepsilon} - A(Q - Q_i)^{\varepsilon}] = A_i + AQ^{\varepsilon}[1 - \varepsilon s_i - (1 - s_i)^{\varepsilon}] \qquad (24)$$

Here, s_i is the share of total driver activity accounted for by service *i*. Table 1 presents values for this difference as a *percentage* of component variable cost, i.e., the term in square brackets, for various values of the cost elasticity and the driver share of service *i*.

share\elast	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
0.1	0.00%	0.05%	0.09%	0.11%	0.13%	0.13%	0.13%	0.11%	0.08%	0.05%
0.2	0.00%	0.21%	0.36%	0.48%	0.54%	0.56%	0.53%	0.46%	0.35%	0.19%
0.3	0.00%	0.50%	0.89%	1.15%	1.30%	1.33%	1.27%	1.09%	0.82%	0.46%
0.4	0.00%	0.98%	1.71%	2.21%	2.48%	2.54%	2.40%	2.06%	1.55%	0.86%
0.5	0.00%	1.70%	2.94%	3.77%	4.21%	4.29%	4.02%	3.44%	2.57%	1.41%
0.6	0.00%	2.76%	4.74%	6.03%	6.69%	6.75%	6.29%	5.34%	3.96%	2.16%
0.7	0.00%	4.34%	7.40%	9.32%	10.22%	10.23%	9.44%	7.95%	5.83%	3.16%
0.8	0.00%	6.87%	11.52%	14.30%	15.47%	15.28%	13.93%	11.59%	8.41%	4.51%
0.9	0.00%	11.57%	18.90%	22.88%	24.19%	23.38%	20.88%	17.05%	12.15%	6.41%
1	#NUM!	90.00%	80.00%	70.00%	60.00%	50.00%	40.00%	30.00%	20.00%	10.00%

Table 1
Difference between Incremental Costs and Attributable Costs as a function of Driver Share and Component Cost Elasticity. (As a percentage of Component Variable Costs)

In Table 1, the rows indicate the fractional share of driver activity caused by the service in question. Thus, a service that accounts for 30% of driver activity has a share of 0.3 in Table 1. The columns indicate the elasticity of variable cost, ε, for the cost component involved. The items in the Table are expressed in percentage terms. Consider, for example, a product that accounted for a 40% share of cost driver activity in a cost component with a cost elasticity of 0.8. Its actual incremental cost would exceed its measured attributable cost by an amount equal to 1.55% of total component variable cost.

Table 1 reveals that the Postal Service measure of component attributable cost understates the value of a product's true incremental cost by only a small percentage amount. For relevant parameter values (i.e., cost elasticity values greater than 0.5), this percentage understatement decreases with the level of cost elasticity and increases with the product's share of driver activity. However, this understatement is less than 3% of component variable cost, even in the case in which the cost elasticity is a very low 0.5 and the share of driver activity is a very high 0.4. In any event, "correcting" Postal Service attributable costs to accurately measure

a product's incremental cost should be a straightforward "spreadsheet calculation" based upon available component cost information. Then, the PRC would have the information upon which to base pricing policy (i.e., unit volume variable costs) and test for cross-subsidization at the product level (i.e., incremental costs).

Indeed, an even more useful and surprising result is available for the important special case in which component variable costs exhibit a constant elasticity: the closeness of the approximation of attributable costs and incremental costs "aggregates" in a simple and intuitive manner. This is an important result. It is well known that a *complete* test for subsidy free prices is that revenues cover incremental costs not only for every individual product, but also for *all* possible proper subsets of products. This is, in general, a daunting task because the number of possible subsets of products increases with the *factorial* of the number of products.[16] However, the task is greatly simplified in the case of a constant elasticity component variable cost function due to the additive structure of attributable costs.

The analysis is essentially the same as that above, however some additional notation is useful. First, let $S \subset N = \{1, 2, \dots, n\}$ denote the (proper) subset of postal products under consideration. Next, let $Q_S = \sum_{i \in S} Q_i$ denote the *total* amount of component cost driver activity accounted for by the product set in question. Finally, let $s_S = \sum_{i \in S} s_i$ denote the *total* share of

[16] For example, for a firm with a product set consisting of 2 products, {1,2} there are only two *proper* subsets to consider: {1} and {2}. However, for a firm with only 3 products there are *six* proper subsets to consider: {1}, {2}, {3}, {1,2}, {1,3} and {2,3}. There 24 such subsets to consider for a firm producing 4 products.

component driver activity accounted for by the products in *S*. Then the above equation relating incremental costs and attributable costs for any product set *S* can be rewritten as:

$$IC_S - \sum_{i \in S} A_i = \sum_{i \in S} F_i + [AQ^{\varepsilon} - A(Q - Q_S)^{\varepsilon}] - \sum_{i \in S}[F_i - Q_i \varepsilon A Q^{\varepsilon - 1}]$$

$$= AQ^{\varepsilon}[1 - (1 - s_S)^{\varepsilon} - \varepsilon s_S] \quad (27)$$

or,

$$IC_S = \sum_{i \in S} A_i + AQ^{\varepsilon}[1 - (1 - s_S)^{\varepsilon} - \varepsilon s_S] \quad (28)$$

Now, it is possible to use Table 1 to address most important pricing policy question facing the Commission. That is, given information on how much volume variable cost has been attributed and distributed to each product at the component level, it is straightforward to calculate an estimate of the *economically relevant* incremental cost for each product *and* for any *group* of products.

6. Conclusions

Attributable Costs as measured by the CRA have a serious shortcoming: they understate incremental costs – the economically relevant standard for testing rates for cross-subsidization. However, the CRA provides the necessary information to correct this shortcoming, allowing incremental costs to be readily calculated.

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Glossary of Terms and Mathematical Functions

Basic Notation

$N = \{1, 2, \ldots, n\}$ – denotes the set of *all* postal products

$S \subseteq N$ – denotes a particular subset of postal products

i – this subscript refers to quantities associated with a particular postal product

j – this superscript refers to quantities associated with a particular postal cost component

Q_i – denotes the quantity provided of product i

D^j – denotes the quantity of cost driver used in cost component j

$\mathbf{Q} = (Q_1, Q_2, \ldots, Q_n)$ – denotes the *vector* (list) of quantities of all postal products

$\mathbf{Q}_S$ = denotes a partial list of product quantities with arguments equal to Q_i for $i \in S$ and 0 for $i \in N/S$.

Postal Cost Terms (and Associated Notation)

Variable Costs, $V^j(D^j)$ – component costs that vary continuously with the level of cost driver activity.

Variability Factor, $\eta^j(D^j)$ – the percentage change in component j costs divided by the percentage change in component driver activity.

Volume Variable Costs, VVC^j – equal to Variable Costs multiplied by the elasticity of component costs with respect to cost driver activity.

Fixed Costs, F^j, – those component costs that do not vary with the level of driver activity.

Specific-fixed costs, F_i, – costs that do not vary with the level of product volume or cost driver activity, but would be avoided if the product were discontinued.

Attributable Costs (Product), A_i, – Specific-fixed costs plus Volume Variable Costs distributed to the product based on its share of cost driver activity.

Infra-marginal Costs (Component), IMC^j –Variable Costs minus Volume Variable Costs

Institutional Costs – Component Fixed Costs plus Infra-marginal Costs = Total Cost minus Volume Variable Cost

Economic Cost Terms (and Associated Notation)

Total Cost, $C(\mathbf{Q})$, – all the expenditures required to produce the specified levels of all of the firm's products

Incremental Costs, $IC_S(\mathbf{Q})$ – the costs that would be avoided if a product (or group of products) were no longer produced = Variable Incremental Cost plus Product-Specific Cost

Stand Alone Cost, $C(\mathbf{Q}_S)$ – the costs of producing a subset of the firm's products in isolation

Marginal Cost, $MC_i(\mathbf{Q})$ – the cost of producing an additional unit of product i

Variable Costs, $V(\mathbf{Q})$ – those costs that vary continuously with the level of output

Marginal Variable Cost, $MV_i(\mathbf{Q}) = MC_i(\mathbf{Q})$ – the marginal variable cost of producing an additional unit of product i. This *always* equals the marginal cost of product i.

Variable Incremental Costs – the variable costs that would be avoided if a product (or group of products) were no longer produced

Elasticity of Variable Costs, ε – this *parameter* is the key cost parameter in the constant elasticity example of Section 5.

Fixed Costs, $F\{S\}$ – those costs that do not vary with the level of output